

Appl. No. «Case__AppSerialNumber»
Amdt. dated May 3, 2011
Reply to Office Action of February 3, 2011

Remarks

Introduction

The claimed invention is directed to an improved cathode material for use in a secondary battery. The inventive cathode material contains (1) LiFePO_4 ; (2) one or more metal elements selected from the group consisting of vanadium (V), chromium (Cr), copper (Cu), zinc (Zn), indium (In), tin (Sn), molybdenum (Mo), and titanium (Ti); and (3) a halogen element.

Status of the Claims

Claims 1-2, 4-7, 9-10, and 12-14 were rejected in the Office Action. Claims 1, 4-6 and 10 are amended herein, and claims 2 and 12-13 are canceled herein. Therefore, claims 1, 4-7, 9-10 and 14 are pending.

Response to the rejection under 35 U.S.C. 112

Claims 1-2, 4-7, 9-10, and 12-14 stand rejected for indefiniteness under 35 U.S.C. 112, second paragraph, since it is unclear how the cathode can contain LiFePO_4 when $n = 0$. Independent claims 1, 4 and 6 have been amended herein so that $n = 1$, and cannot be 0. This amendment is believed to fully overcome the indefiniteness rejection under 35 U.S.C. 112, second paragraph.

Appl. No. «Case__AppSerialNumber»
Amdt. dated May 3, 2011
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Response to the Art Rejections

Claim 1 stands rejected under 35 U.S.C. 102(b) as being anticipated by Nakamura et al. JP 2002-198050 ("Nakamura"). Claims 1-2, 5-7, 9-10, and 12-14 stand rejected under 35 U.S.C. 102(b) as being anticipated by Ravet et al., U.S. Patent No. 6,855,273 ("Ravet"). Claims 1 and 4 stand rejected under 35 U.S.C. 102(b) as anticipated by or, in the alternative, under 35 U.S.C. 103(a) as obvious in view of, Nakamura. Claims 1-2, 4-7, 9-10, and 12-14 stand rejected under 35 U.S.C. 102(e) as anticipated by or, in the alternative, under 35 U.S.C. 103(a) as obvious in view of, Ravet. Finally, claims 1, 4-7, 9-10, and 12-14 stand rejected under 35 U.S.C. 103(a) as being unpatentable over Nakamura in view of Ravet.

In response to the art rejections, claims 1, 4 and 6 have been further amended herein to incorporate the limitations of now-canceled claim 2 (that the one or more metal elements are "selected from the group consisting of vanadium (V), chromium (Cr), copper (Cu), zinc (Zn), indium (In), tin (Sn), molybdenum (Mo), and titanium (Ti)") and now-canceled claims 12 and 13 (that the halogen element is present "in a molar concentration of up to twice that of the metal element or elements"). Additionally, dependent claims 5 and 10 have been amended in order to correct their dependencies.

The present invention, as now claimed, contains critical limitations in terms of both the selection of certain metal constituents and the selection of ranges of concentrations of the metal and the halogen, which results in vastly improved performance of the resulting cathode material. As discussed below, the criticality of these selections is nowhere recognized in the cited art.

Appl. No. «Case_AppSerialNumber»
Amdt. dated May 3, 2011
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For example, the invention according to amended claim 1 requires the following:

- <1> a cathode material for a secondary battery containing a cathode active material represented by a general formula Li_nFePO_4 (wherein n equals 1) as a primary component;
- <2> the cathode material contains one or more metal elements exclusively selected from the group consisting of vanadium (V), chromium (Cr), copper (Cu), zinc (Zn), indium (In), tin (Sn), molybdenum (Mo), and titanium (Ti);
- <3> the total content of the metal elements is exclusively in the range of 0.1 to 5 mol%, in terms of element ratio, based on iron in the cathode active material; and
- <4> the cathode material contains a halogen element in an amount of 0.1 mol% or more based on P, and in a molar concentration of up to twice that of the metal element or elements.

It is noteworthy that the invention of amended claim 1 is characterized in that:

- (i) the cathode material **does not contain any metal element belonging to Group 7 to 10, such as Mn, Co, and Ni**, of the Periodic Table but contains exclusively the above-mentioned metal elements, with the total content of the metal elements exclusively in the range of 0.1 to 5 mol%, in terms of element ratio, based on iron in the cathode active material; and
- (ii) the halogen element is contained in an amount of 0.1 mol% or more based on P and in a molar concentration of up to twice that of the metal element or elements.

By requiring specifically selected metal elements with the content thereof in a specific, selected range, and by requiring a halogen element in a specific, selected amount, the cathode

Appl. No. «Case__AppSerialNumber»
Amdt. dated May 3, 2011
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material of the present invention exhibits remarkably improved cycle characteristics in the discharge capacity of the resulting secondary batteries, as illustrated in Reference Figures 1 and 2 (attached hereto).

Reference Figure 1 demonstrates the criticality of the fact that the present invention contains no metal elements belonging to Group 7 to 10 of the Periodic Table, such as Mn, Co, Ni, etc., but contains only the above-mentioned metal elements. As shown in Reference Figure 1, the cycle characteristics of the cathode materials containing Mn, Co, Ni or Mg (which would be encompassed within the cited art) deteriorate significantly, compared to those of the cathode materials containing the metal elements according to the present invention (Cu and Zn in Reference Figure 1).

Reference Figure 2 demonstrates the criticality of the fact that the the metal elements in the present invention are present exclusively in the range of 0.1 to 5 mol%, in terms of element ratio, based on iron in the cathode active material. The cathode material represented by the uppermost cycle characteristics line in Reference Figure 2 contains the metal Cu in a total amount of 1 mol%, substituted for 0.5 mol% of Li and Fe, respectively. The other cycle characteristics lines represent cathode materials containing Cu in five times that amount, or in an amount of 5 mol%. It is shown that the initial discharge capacity deteriorates with a larger amount of Cu. For this reason, 5 mol% would be the upper limit. Incidentally, Reference Figures 1 and 2 also show the presence of halogen (chlorine) within the claimed critical range.

Appl. No. «Case__AppSerialNumber»
Amdt. dated May 3, 2011
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These critical features of the present invention, resulting in vastly improved performance characteristics, now will be compared with the disclosures of the cited art.

Nakamura discloses in its paragraph [0016] that the cathode material contains at least one metal element other than Fe, Li or Al, among which Co, Mn and Ni are preferable. Thus, the cathode material of Nakamura can contain essentially any metal element – including many which yield inferior performance – but all of which are considered to be interchangeable. Nakamura also discloses that the content of the metal element is $0 \leq y \leq 0.5$, which permits a content about one order greater than that in the present invention. As was made clear in the discussion of Reference Figure 2, the upper limit on metal content is critical to the performance of the resulting cathode material, but this is neither taught nor suggested by Nakamura.

Thus, it is apparent that Nakamura does not at all recognize the technical significance of the cathode material containing specific, selected metal elements with the content thereof in a specific, selected range, as required by the present invention.

The present invention also distinguishes patentably over Ravet, since Ravet similarly fails to recognize the criticality of the limited set of metal elements required in the present invention (i.e., one or more metal elements selected from the group consisting of vanadium (V), chromium (Cr), copper (Cu), zinc (Zn), indium (In), tin (Sn), molybdenum (Mo), and titanium (Ti)). Ravet further contains no description or suggestion that specifies the content of the metal element based on iron (Fe) in the cathode active material, much less any recognition of a critical content range.

Appl. No. «Case__AppSerialNumber»
Amdt. dated May 3, 2011
Reply to Office Action of February 3, 2011

Additionally, Ravet only describes that halogen is contained as a substitute for oxygen atoms in PO_4 constituting the active material, and it does not describe or suggest the critical relationship between the content of halogen and the cycle characteristics.

Thus, Nakamura and Ravet, when considered either individually or together, neither teach nor suggest the cathode material of the present invention which contains:

- specific, selected metal elements (excluding, e.g., Mn, Co, Ni, etc.);
- wherein the metal elements are present in a specific, selected amount that is based on the amount of iron in the material; and
- a halogen element in a specific, selected amount;

all of which are critical to the improved cycle characteristics in discharge capacity of resulting secondary batteries (as shown in Reference Figures 1 and 2 hereto, as well as FIGs. 5 to 14 of the instant application).

Further, it should be noted that the invention in “product-by-process” claim 4 is a cathode material for a secondary battery synthesized by mixing a halide or halides of the metal element or elements with the ingredients of the cathode active material, and then calcining the mixture. Thus, in the invention of claim 4, a halide or halides of the metal element or elements are used as the ingredients. In this way, a cathode material can be easily produced which contains the metal element or elements and also the halogen element or elements (as residues). The thus produced cathode material for a secondary battery yields improved cycle characteristics as discussed

Appl. No. «Case__AppSerialNumber»
Amdt. dated May 3, 2011
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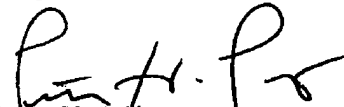
herein. In contrast, Nakamura does not describe the production method in detail, and certainly does not describe the use of a halide or halides of a metal element or elements. The same is true of Ravet.

Finally, since the dependent claims include every element of the respective independent claims, the dependent claims also distinguish patentably over the cited art.

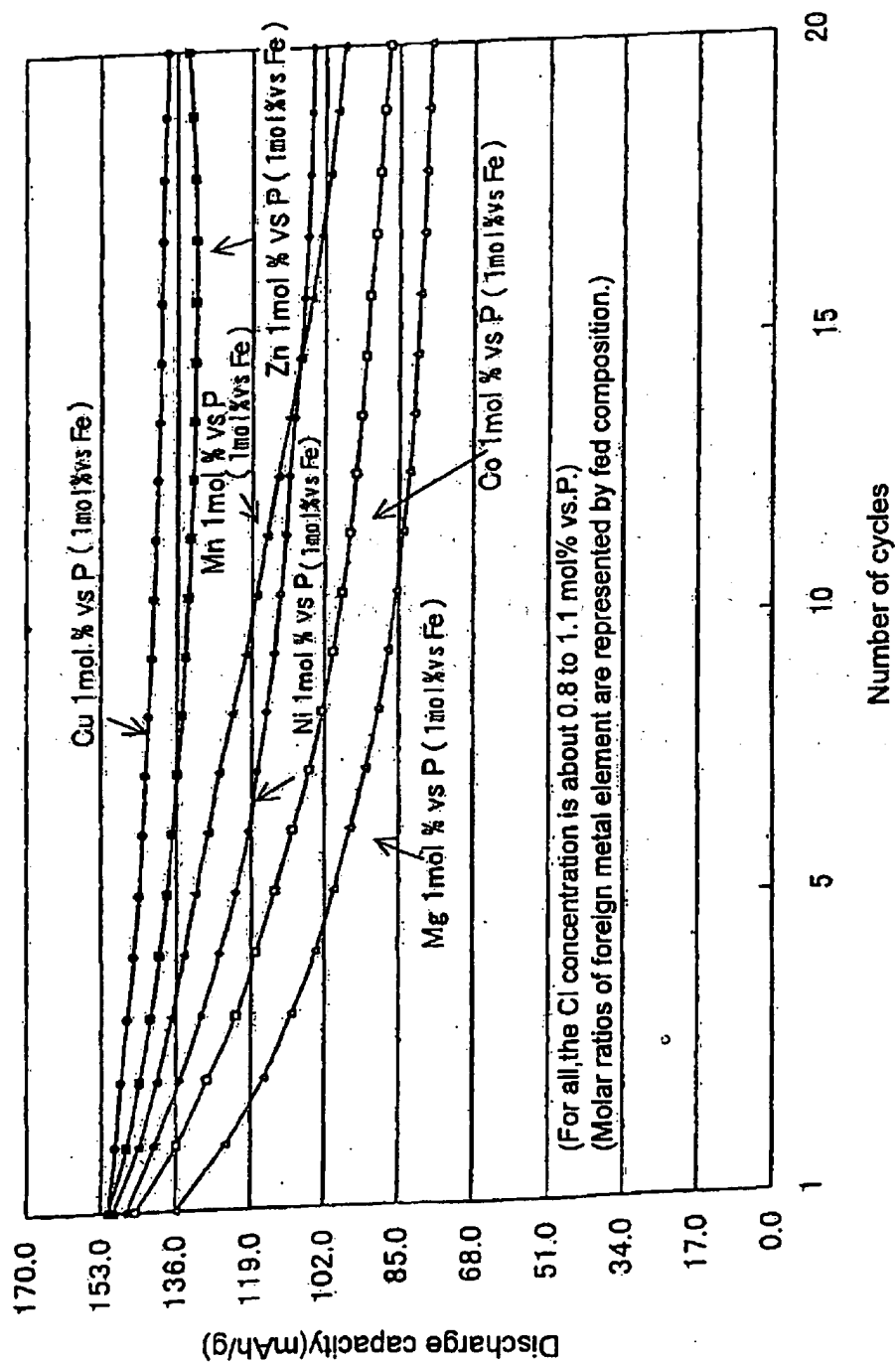
Conclusion

All of the presently pending claims, as amended, appearing to define over the applied references, withdrawal of the present rejection and prompt allowance are requested.

Respectfully submitted,


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[Reference Figure 1]



[Reference Figure 2.]

